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Studia breviora

Ash aggregates in the Borovitsa caldera outflow deposits (eastern Rhodopes, South Bulgaria)

Aggregation is a common process in particle-gas mixtures, such as ash clouds generated by explosive volcanic eruption. Varying in size and structure, ash aggregates have been reported from different in age pyroclastic sections in Bulgaria, the majority of them being Palaeogene and located in South Bulgaria (Janev, 1965; Harkovska, 1983, 1984; Harkovska and Velinov, 2002; Harkovska *et al*., 1998; Vatsev, 2002; Yanev, 2017, etc.). They have been interpreted as fallout or base-surge deposits resulting from subaerial phreatomagmatic explosive activity (Harkovska, 1998).

In the eastern Rhodopes, ash aggregates were observed to the west of the village of Perperek (Chiflik Volcanic Subcomplex, Yordanov *et al*., 2008). They also seem typical of the explosive products related to the activity in the area of the Borovitsa caldera (BC). The BC is the largest (~34 × 15 km) Palaeogene volcanic structure in the Eastern Rhodopes, recently defined as “large caldera system” or “supervolcano” (Yanev, 2017). Ash aggregates were found in the caldera fill deposits (tuffaceous formation, Yanev, 2017), as well as in the BC outflow tuffs (Ivanova, 2012; Ivanova *et al*., 2013) exposed right to the south of the BC bounding fault near the village of Zhenda. Some “aggregation” seems also present in the corresponding deposits occupying the topmost parts of the pyroclastic section exposed to the southwest of Kostino Village (about 14 km to the south of BC). These two distinct types of aggregates are briefly described in this paper.

Ash aggregates with concentric structure are observed in the BC outflow section located to the north of Zhenda Village where an over 300-m thick pyroclastic succession lies over terrigenous-tuffaceous rocks with plant detritus (Yanev, 1990). Due to a well-developed talus cone, the lower half of the section was not observed. The upper 150 m of the section (32.64±30 Ma, Marchev *et al*., 2013) consist of three massive and coarse-grained ignimbrite units, of which only the middle one (~130 m thick) is fully exposed. The lower two ignimbrites are covered by finer-grained layers (about 2 m thick) interpreted as fall deposits as the ash aggregates occur in the lower one (Fig. 1*a*, N 41°46′774; E 25°10′662). The aggregate-bearing rocks are fine to coarse ash-sized and clearly laminated due to alternation of layers with different proportions of crystal, dense lava and glass fragments. The latter are replaced by zeolite (Alexiev *et al*., 1997) and look red due to Fe-oxyhydroxides. The ash aggregates form several “aggregate”-supported beds (2–4 cm thick, Fig. 1*a*) or are scattered in the “matrix”-supported levels (Fig. 1*b*). Being poorly visible on weathered surface, they become almost invisible on freshly broken and polished surface. After wetting the specimen, they appear in a short time, since the rims dry slower than the cores and matrix (Fig. 1*b*). The aggregates have coarse-grained core and fine-grained periphery (Fig. 1*b*, *c*), *i.e*., they are rim-type accretionary lapilli (Schumacher and Schmincke, 1995) or pellets with concentric structure of AP2-type (Brown *et al*., 2012). They vary in size from 2 mm to 4 mm. Single aggregates seem larger but are always slightly elongated. The rims are 0.2–0.3 mm thick and are commonly well individualized (Fig. 1*b*, *c*). They consist of better-sorted and finer-grained material than those in the cores and matrix. Rarely, gradual decrease in grain-size of the particles towards the periphery was observed (Fig. 1*d*). Regarding the mode of their formation, it is now considered (*e.g*., Brown *et al*., 2010; Van Eaton and Wilson, 2013) that AP2-type ash pellets are more likely to form in plumes, elutriated from moving pyroclastic flows [source of so-called co-ignimbrite or co-PDC (pyroclastic density current) fallouts] rather than in vent-derived clouds. The observed close association between aggregate-bearing fall deposits and ignimbrite units in the area of BC (Yanev, 2017) coincides well with this consideration. Interaction with Plinian type eruptive columns (Van Eaton and Wilson, 2013) can also be proposed, presuming large volumes and high intensity of the explosive activity in the area resulting in BC col-

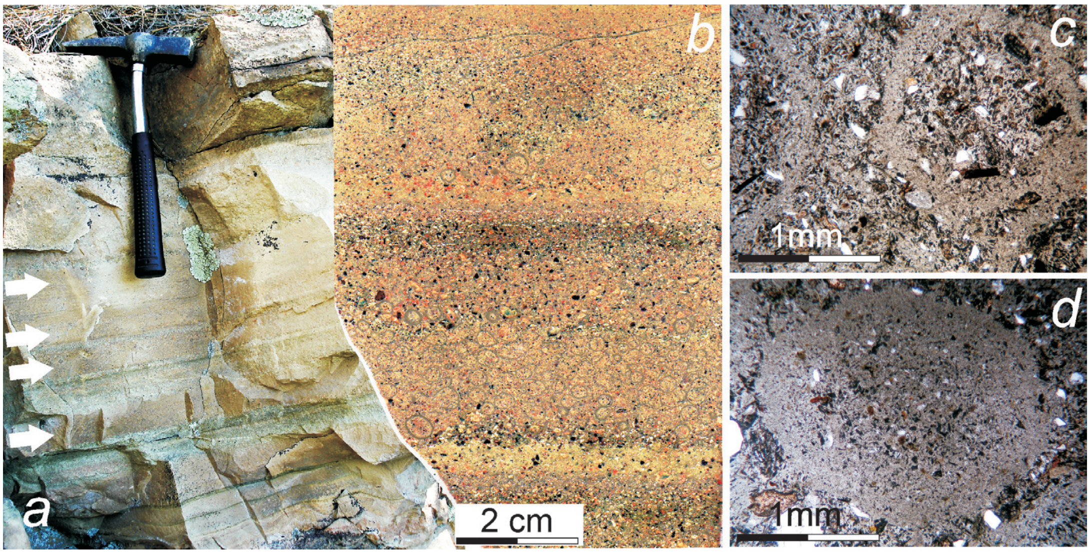

Fig. 1. Ash aggregates in the Borovitsa caldera outflow deposits, Zhenda Village; *a*) aggregate-bearing fallout tuffs (arrows indicate "aggregate"-supported beds); *b*) polished hand specimen showing an "aggregate"-supported bed (the contrast of the image is strongly enhanced); *c, d*) microphotographs taken under cross-polarized light.

lapse. Moreover, the Palaeogene sea-shore may also have been close enough to provide additional turbulence, moisture, salt, etc., conditions favouring aggregation of the finest particles in volcanic plumes (Burns *et al*., 2017, and the references therein).

The second type of "ash aggregation" is observed in the pyroclastic section exposed to the west of Kostino Village. Both sections (near Zhenda and Kostino) share some common features, although direct correlation of the individual units is not possible (Ivanova, 2012). The section near Kostino Village is about 80 m thick and consists of six flow units (ignimbrites), associated with ash-cloud and fallout units, enriched in marine fossil

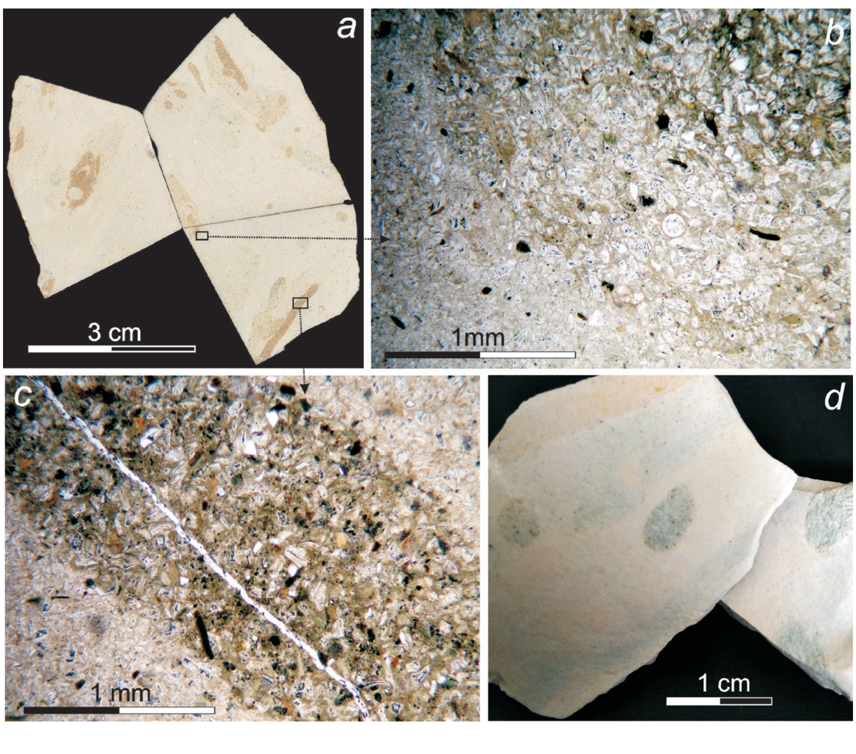

Fig. 2. Bioturbation in the Borovitsa caldera outflow deposits, Kostino Village; *a, d*) hand specimens; *b, c*) microphotographs showing variation in grain-size (plane-polarized light).

remnants. Their presence in flow units suggests sufficient mixing with marine water before deposition, *i.e*., transition from hot gas-supported to cold water-supported flows. The "aggregates" occur (or are only visible) in some of the finest-grained ash-cloud units and, although some have ordinary morphology (Fig. 2*d*), most of them possess particular shapes (Fig. 2*a–c*). Regardless of their morphology, they are always coarser-grained than the enclosing matrix. Even the finer-grained periphery, when is present (Fig. 2*b*), is still coarser-grained than the matrix. Respectively, these objects completely differ in nature from the ash aggregates described in the first occurrence, which causes "premature" sedimentation of the finer-grained particles. The "aggregates" in the Kostino section are biogenic in origin (bioturbation), most probably indicating periods of low influx rate of new pyroclastic material into the basin. Therefore, at least three repose (or low activity) periods between eruptions are recorded in the BC outflow pyroclastic section near Kostino Village.

REFERENCES

Aleksiev, B., Djourova, E., Milakovska-Vergilova, Z. 1997. Geology of the Oligocene zeolitic rocks in NE Rhodopes, Bulgaria: a review and new data. *In*: Kirov, G., Filizova, L., Petrov, O. (Eds), *Natural Zeolites, Sofia'95*. Pensoft, Sofia-Moscow, 249–262.

Brown, R.J., Bonadonna, C., Durant, A.J. 2012. A review of volcanic ash aggregation. *Physics and Chemistry of the Earth* 45–46, 65–78.

Brown, R.J., Branney, M.J., Maher, C., Davila-Harris, P. 2010. Origin of accretionary lapilli within ground-hugging density currents: evidence from pyroclastic couplets on Tenerife. *Geological Society of America Bulletin* 122, 305–320.

Burns, F.A., Bonadonna, C., Pioli, L., Cole, P.D., Stinton, A. 2017. Ash aggregation during the 11 February 2010 partial dome collapse of the Soufrière Hills Volcano, Montserrat. *Journal of Volcanology and Geothermal Research* 335, 92–112.

Harkovska, A. 1983. Spatial and temporal relations between volcanic activity and sedimentation in the stratified Paleogene from the central parts of Mesta Graben (SW Bulgaria). *Geologica Balcanica* 13 (3), 3–30.

Harkovska, A. 1984. Accretionary lapilli tuffs from the Smolyan Palaeogene (South Bulgaria). *Comptes rendus de l'Académie bulgare des Sciences* 37, 1355–1358.

Harkovska, A. 1998. Reconstruction of the Paleogene volcanic structures in Bulgaria – main problems and tasks. *Annuaire de l'Université de Sofia* 90, 131–159 (in Bulgarian, with English abstract).

Harkovska, A., Velinov, I. 2002. New data on the genesis of the Stomanovo secondary quartzites deposit (Central Rhodopes). *Mining and Geology*, 57 (9), 27–33 (in Bulgarian, with English abstract).

Harkovska, A., Marchev, P., Machev, Ph., Pecskay, Z. 1998. Paleogene magmatism in the Central Rhodope area, South Bulgaria – a review and new data. *Acta Vulcanologica* 10 (2), 199–216.

Ivanova, R. 2012. Pyroclastic stratigraphy of the acid volcaniclastics (2nd Rupelian phase) near Plazishte (Dzhebel) and Kostino (Kardzhali) villages, Eastern Rhodopes – a comparative study. *Bulgarian Geological Society, National Conference with International Participation "Geosciences 2012", Abstracts*, 83–84.

Ivanova, R., Yanev, Y., Machiels, L., Elsen, J. 2013. Eruptive history and source area of acid volcaniclastics from northern parts of Dzhebel depression (Eastern Rhodopes, South Bulgaria) as inferred from the pyroclastic stratigraphy and petrography. *Review of the Bulgarian Geological Society* 73 (1–3), 41–67.

Janev, S. 1965. Über die anwesenheit von pisolithtuffen und einem voroberstefanischen vulkanismus in Iskăr-Durchbruch. *Bulletin of the "Strašimir Dimitrov" Institute of Geology* 14, 211–221 (in Bulgarian, with German abstract).

Marchev, P., Harkovska, A., Pécskay, Z., Panteva, V., Popov M. 2013. Geology, petrology and K-Ar geochronology of Topolovo-Pilashevo dyke swarm (TPDS) and lavas from the NW Borovitsa volcano (Eastern Rhodopes, Bulgaria). *Acta Vulcanologica* 25 (1–2), 99–110.

Schumacher, R., Schmincke, H.-U. 1995. Models for the origin of accretionary lapilli. *Bulletin of Volcanology* 56, 626–639.

Vatsev, M. 2002. Paleogene accretionary lapilli tuffs in Mesta graben (South-Western Bulgaria). *Annual of the University of Mining and Geology "St Ivan Rilski"* 45 (1), 29–34.

Yanev, Y. 1981. The volcanism in Momchilgrad depression and Arda graben-syncline. *In*: Harkovska, A., Yanev Y. (Eds), *Palaeogene volcanism in the Mesta graben, Central and Eastern Rhodopes (South Bulgaria)*. Guide-book of working group 3.4 Field trip. Problem commission IX of the Academy of Sciences of the socialist countries, Sofia, 46–55 (in Russian).

Yanev, Y. 1990. *Evolution of the Acid Volcanism of the Borovitsa Caldera and its Frame*. Unpublished Habilitation Thesis. Geological Institute of Bulgarian Academy of Sciences, Sofia, 183 pp. (in Bulgarian).

Yanev, Y. 2017. On the geology and volcanology of the Paleogene Borovitsa caldera and its frame (Eastern Rhodopes, Bulgaria). *Review of the Bulgarian Geological Society* 78, 97–128 (in Bulgarian, with English abstract).

Yordanov, Y., Sarov, S., Georgiev, S., Valkov, V., Balkanska, E., Grozdev, V., Marinova, R., Markov, N., Kolcheva, K., Banushev, B., Sinyovski, D. 2008. *Explanatory notes for the geological map of Bulgaria in scale 1:50 000, Knizhovnik map sheet*. Ministry of Environment and Water, Bulgarian National Geological Survey, Sofia, 95 pp.

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